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23 September 1964

Dear Joe:

Subject: Final Report - Frame-by-Frame Exposure Control Printer (Galaxie), Contract EG-400

Submitted herewith are two (2) copies of the subject report.

Dick

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OSA # 2511-64
cy 1 of 3

FINAL REPORT

Frame-by-Frame Exposure Control Printer
(Galaxie)

26 August 1964

Prepared by:
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Approved by:

EG-400

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SUMMARY

The Galaxie Printer was developed to solve problems of reconnaissance photography where exposure in consecutive frames varies greatly. Requirements demanded that any different exposure necessary during printing must be changed as the frame interspace passes the exposure plane. Also, that the operation be accomplished on a continuous type printer without interruption or reduction in printer capability.

An entirely new lamp house featuring alternating light paths and an electronic arrangement to program exposure changes was designed, fabricated, and adapted to a standard Niagara Printer. Tests with the prototype Galaxie Printer have proven the validity of the design and demonstrated that frame-by-frame exposure correction is both desirable and practical.

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SUBJECT: Frame-by-Frame Exposure Control Printer (Galaxie)

TASK/PROBLEM

1. Develop a printer with the capacity of changing light level delivered to the printing gate during passage of a frame line under the gate and thus provide different controlled levels of exposure for individual frames.

INTRODUCTION

2. In the past, printing exposures for continuous duplication of aerial reconnaissance photography have been relatively uniform and, while it has been customary to correct for exposure deficiency in an interrupted processor, such correction has only been accomplished on a trend basis. For continuous printing, it has been the practice to break the negative into parts requiring equal printer exposure. The frame-by-frame exposure control printer was conceived as a solution to the problems of mission photography in which the exposure of consecutive frames vary greatly.

3. Design Requirements Established for the Frame-by-Frame Printer Were:

a. Must be a continuous high-quality production type printer.

b. Exposure change (correction) between adjacent frames must be accomplished entirely within interframe spacing.

DISCUSSION

4. A prototype frame-by-frame printer designated the Galaxie was completed and has undergone initial testing. Figure 1 illustrates an over-all view of the prototype Galaxie including the electronics package. Figure 2 shows the printer threaded with film and ready for operation.

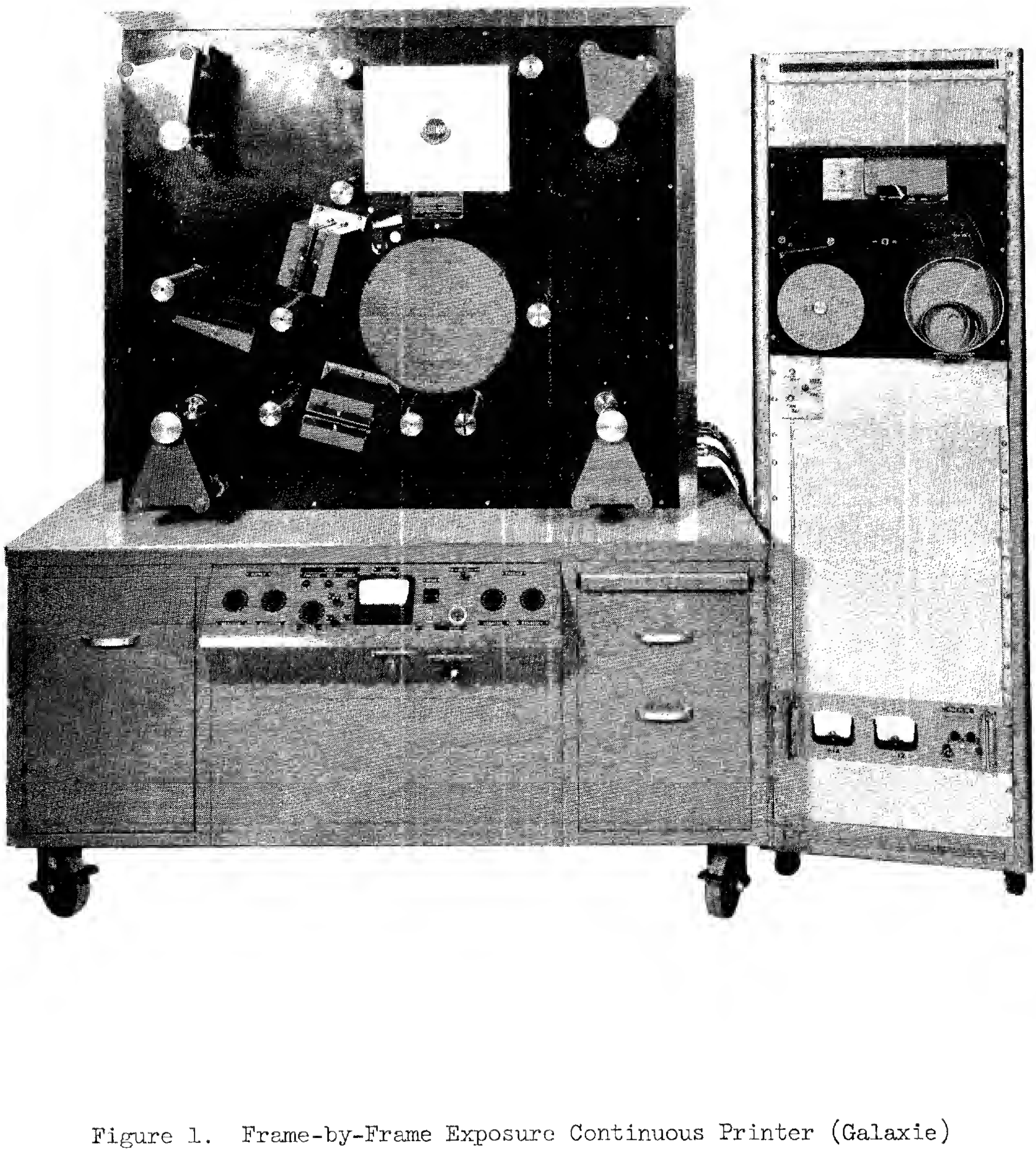


Figure 1. Frame-by-Frame Exposure Continuous Printer (Galaxie)

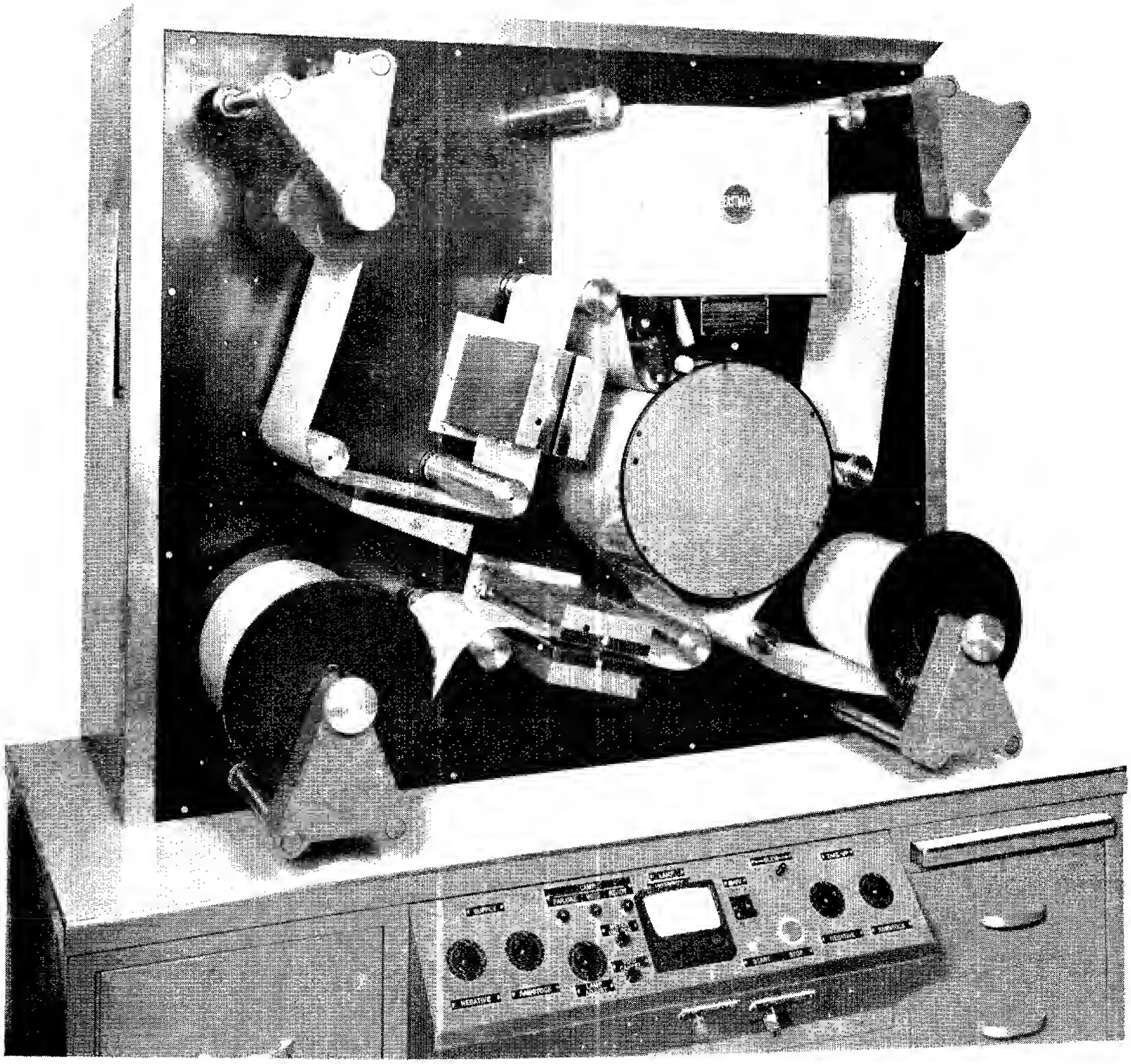


Figure 2. Galaxie Printer Threaded and Ready for Operation

5. Frame-by-Frame Printing System: Corrected duplication of negatives with frame-to-frame differences in printing level requirements depends on a complete system. In addition to the Galaxie Printer, the system includes:

a. Tape Punch: A Friden Add-Punch was purchased, modified, and used to program the exposure changes. The machine produces a coded 8-channel tape set up to correspond with the predetermined exposure required for each frame in the roll of negative film.

b. Titler: A titler, developed on another contract, was adapted to apply a magnetic coding mark at the frame lines of the negative, prior to printing, to indicate the point of exposure change.

6. Mechanical-Optical Design:

a. A Niagara Printer was redesigned so that the desired exposure change could be accomplished within interframe spacing. As a basic Niagara, the instrument is a high resolution, low distortion printer capable of producing duplicate films at a rate of 82.5 feet per minute. Original negative in any width from 70mm to 9.5 inches and in continuous lengths on rolls up to 1000 feet can be reproduced onto duplicating materials of identical sizes.

b. Major changes that converted the Niagara to a Galaxie frame-by-frame printer involved replacing the lamp house with a unit of entirely new design and adding an electronic system to control exposure from frame to frame. Lamp house configuration for the Galaxie printer is shown in Figure 3. The key features are the light source, shutter, and alternate light paths which operate according to an idea pioneered by Kodak for continuous motion picture projection -- short duration lap dissolve -- to accomplish frame-by-frame exposure interchange. Principal items in the lamphouse design are:

(1) Light Source: The light source must be either a point or a line to furnish variable intensity without overlap or a gap greater than the interframe spacing between negatives. Thus, the 100-watt mercury

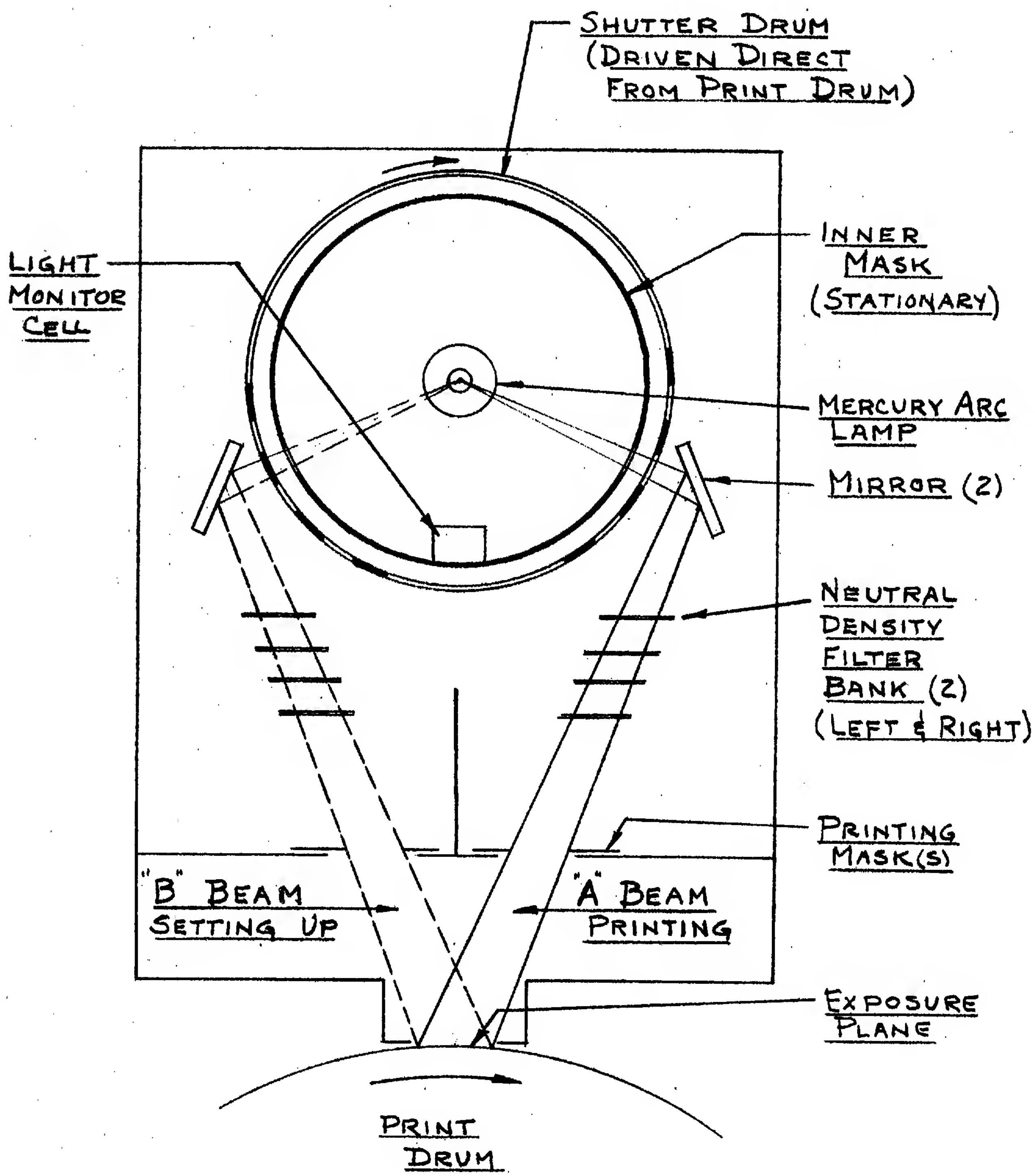


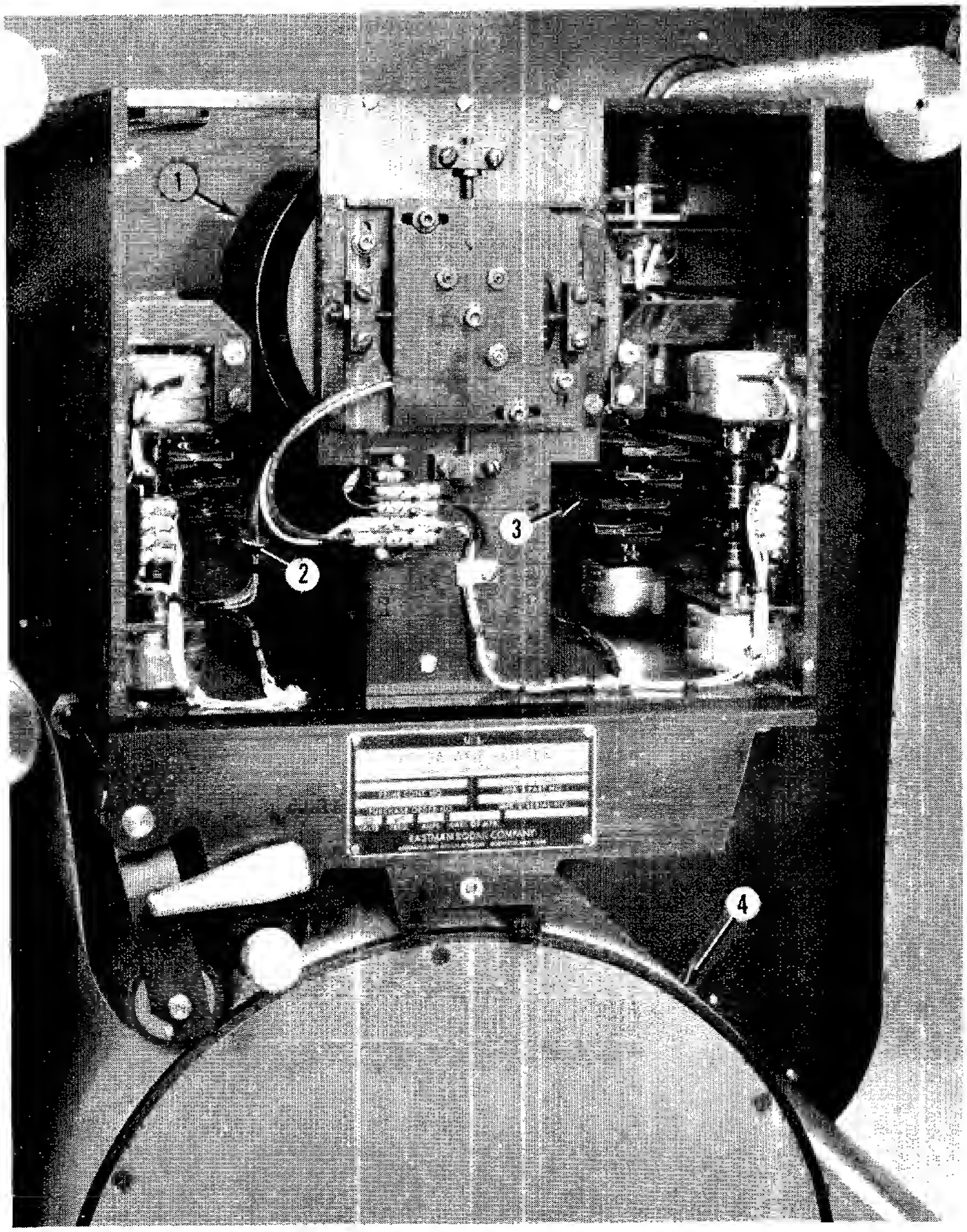
Figure 3. Galaxie Printer Lamp House Configuration

arc lamp normally used in the Niagara lamp house was used in the Galaxie. Also, there is a light monitoring cell inside the lamp house that is coupled to a meter on the printer control panel to indicate lamp condition.

(2) Shutter: Light reaches the printing drum via one of two paths selected by a rotary shutter surrounding the printing lamp. (See Figures 3 and 4.) Shutter rotation is synchronized with the printing drum so that the image of the shutter edge travels across the printing slit at precisely the speed of film motion.

(3) Alternate Light Paths: Figure 3 also illustrates how light reaches the printing drum by either one of two paths. While one light path is printing (Beam A), the alternate path is being set up for the next exposure change (Beam B). Light leaving the printing lamp is reflected off a mirror and then travels through a neutral density filter bank, through an appropriate printing mask (selected before printing to match film width), and onto the printing drum. The appropriate combination of neutral density filters is programmed according to the required exposure and inserted into the light path by the electronic system.

7. Electrical Design: Chief features of the electrical design are the input control logic mounted in the control console and the magnetic pick-up head attached to the lamp house. Prior to printing, densitometric data (on a frame-by-frame basis) for each roll of negatives is punched into an eight-channel tape of the type used in business machines. This tape is read out on the input control logic which feeds an electronic signal to trigger the appropriate solenoids attached to the neutral density filters in the light paths. The points of exposure change are controlled at each frame by magnetic marks applied to the negative before printing. These marks are sensed by the pick-up head and pulsed to the input control logic to indicate need for an exposure modulation.



1. Rotating Shutter Drum
2. Left Neutral Density Filter Bank
3. Right Neutral Density Filter Bank
4. Print Drum

Figure 4. Galaxie Lamp House with Front Cover Removed

8. Testing Program: The Galaxie printer was released to Quality Control for testing at various times between February and mid June 1964. Unless otherwise indicated, the raw material used for testing was Kodak Aerographic Duplicating Film, Type 5427. These tests have proven the validity of the design concept and have demonstrated that frame-by-frame exposure correction is practical. During these tests, various printer characteristics listed below were evaluated.

a. Tracking: Film sizes of 70mm, 5 inches, 6.6 inches, and 9.5 inches were found to track within ± 1/32 inch, the tolerable limit for Niagara printers. This limit was also true for 70mm and 9.5-inch Estar base films three millimeters thick.

b. Print Drum Speed: The print drum drives the film at 61.5 feet per minute; this speed cannot be changed unless gears and associated equipment are replaced within the drive mechanism.

c. Exposure Level: Initial testing indicated that the Galaxie was slower in exposure than a Niagara. This problem was partially solved by replacing a faulty lamp delivered with the printer. A further correction was made by operating the lamp at 98 watts rather than at the usual 77-watt level established for Niagara printers. The 98-watt level was considered to be the maximum which would still permit reasonable lamp life. With these changes, the Galaxie operated at 0.13 log exposure units below the Niagara standard control level. This difference pertained to both light paths, A and B.

d. Uniformity of Exposure: Density measurements across the printing web were made on a transverse section of 9.5-inch flashed film. Density across the web varied 0.10 or less using a process gamma of 1.0.

e. Light Attenuation: The bank of four Wratten 96 filters situated beside each light beam produces 15 modulation steps to vary the illumination of the printing lamp. Each bank has filters of 0.1, 0.2, 0.4, and 0.8 neutral density that furnish a density range from 0.0 to 1.5 in increments of .1. The resulting photographic effect was a shift of the D-log E curve in 0.14 log E increments with a total log exposure range from 0.0 to 2.10 units. This is based on use of the resolution-improving (Corning 5970) filter during exposure and the new process specification no. 623, both of which are standard when using Type 5427 film.

f. Resolution: High contrast resolution charts were printed on Type 5427 and Type 8430 duplicating materials. The charts were 9.5-inches wide with 11 resolution targets uniformly spaced across the printer drum. The results from one test using each type of material are shown in Table 1.

g. Frame Length Capability: The printer worked well with frame lengths of 5 inches or greater. Frame lengths up to 18 inches were tested successfully and, based upon the principles of the machine, no maximum limit exists.

h. Frameline Transition: As the printer switches from beam A to beam B (see Figure 3), a smear appears transversely on the film. The smear results from the action of the shutter drum and was excessively wide. The smear image would alternate from dark to light along succeeding framelines. This problem was reduced to tolerable limits by adding a stationary mask (see Figure 3) near the lamp and replacing a single printing aperture near the exposure plane with two adjustable printing masks located inside the lamp house. These masks were adjusted so that beam A and beam B would subtend the same arc of the print drum. As a result, the width of the transition smear was reduced to 3/16 inch which falls within the 1/4-inch space normally available between frames.

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TABLE 1

RESOLVING POWER
(lines per mm)

Type 5427 with 5970 Filter A Beam	Type 5427 with 5970 Filter B Beam	Type 8430 A Beam	Type 8430 B Beam
221	278	398	397
278	278	397	354
278	278	354	354
278	278	354	354
278	317	354	354
317	278	354	317
278	278	317	354
278	278	354	317
250	278	397	397
317	317	397	397
---	317	397	354

(Average equals 270 lines per mm) (Average equals 350 lines per mm)

These results indicate that resolution from the Galaxie Printer is as good or better than resolution obtained from a standard Niagara Printer.

i. Mechanical Performance: Some difficulty exists with the adjustment of the magnetic pick-up head suspension mechanism. The mechanism is difficult to position for various sizes of film. Also, the height adjustment which carries the pick-up head above the film must be redesigned to permit:

(1) Finer control of height adjustment.

(2) Maintenance of the critical film-to-magnetic-head spacing at all positions across the print drum.

(3) Maintenance of the critical film-to-magnetic-head spacing for all film base thicknesses.

A further mechanical difficulty was discovered in the filter holding brackets of the neutral density filter bank. Current brackets permit shifting and buckling of the gelatin material. Production models of the Galaxie Printer will incorporate filters of a new design that will eliminate this difficulty.

j. Electrical Performance: The following electrical problems were encountered:

(1) Transient signals were sporadically produced when the "start" button was depressed. These signals would advance the paper control tape and thus destroy synchronization between the control tape and the negative being printed. This problem was corrected.

(2) The image of the transition line relative to the position of the magnetic mark image changed. (Note the magnetic mark in the frameline in Figure 5.) The fluctuation of the transition line position appeared at various locations of the pick-up head across the print drum; however, later evidence showed that this lateral fluctuation was caused by variation of the critical film-to-magnetic head spacing (see paragraph 8i(3)).

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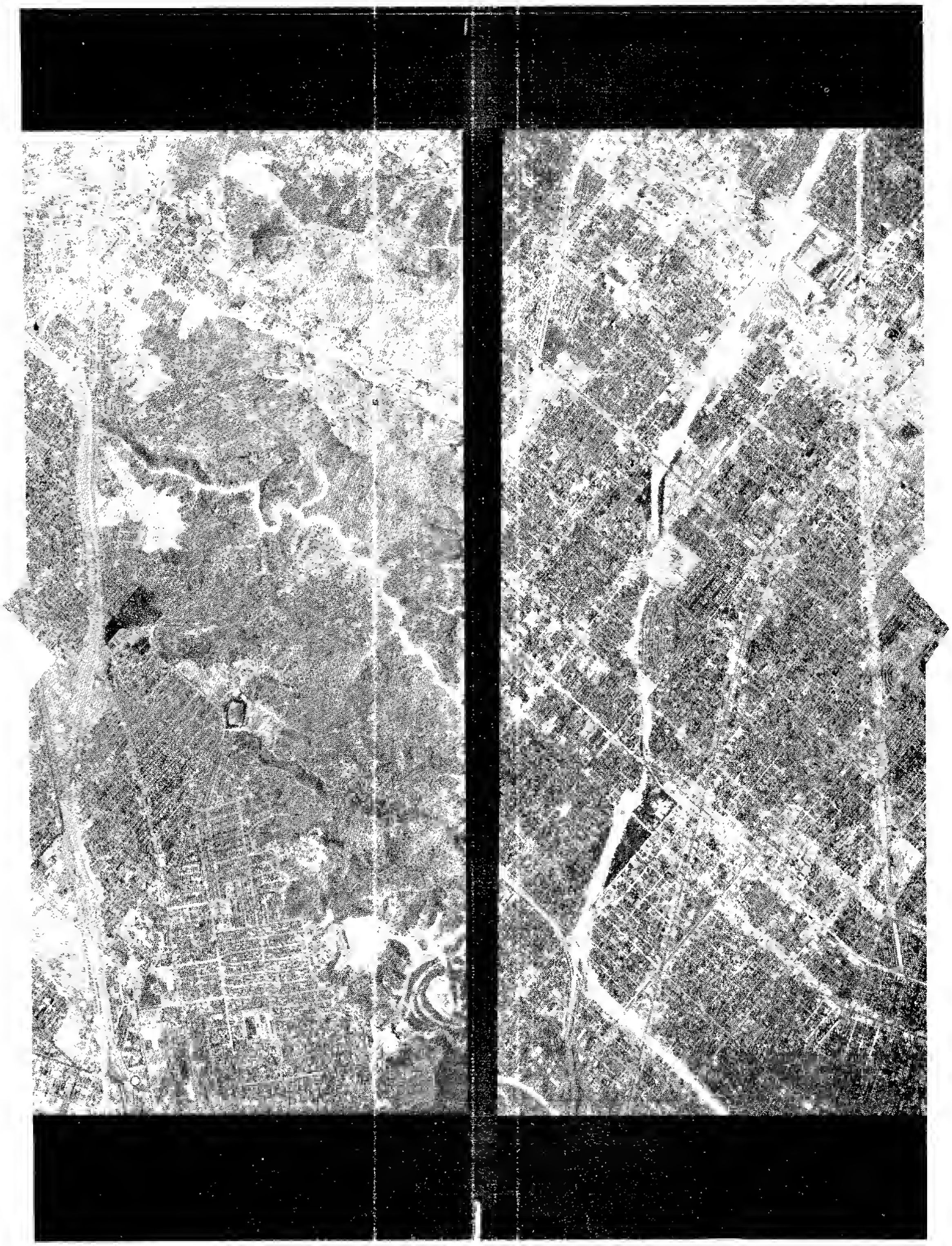

Figure 5. Typical Interframe Transition

(3) In some instances, the filters which shifted into the light path differed radically from the combination of filters summoned by the control tape. This occurrence was sporadic, and, in each instance, the frame printed was dense indicating a filter was never positioned or fell out of position. Transient signals in the circuitry were again believed to cause this mishap, and, subsequently, shielding, filters, and grounds were added where necessary to subdue these transients. Although no tests were run for this specific purpose, evidence of wrong filter combinations was not noted in test runs after circuit modifications.

CONCLUSIONS

9. Frame-by-frame exposure correction is feasible with continuous printers.

10. The prototype Galaxie printer satisfies the program objectives.

RECOMMENDATION

11. That a production model of the Galaxie Printer be engineered (correcting noted deficiencies), fabricated, and installed in the production facility.

REFERENCES

1.	Project Authorization Request, Frame-by-Frame Exposure Control Printer (Galaxie), PAR 13	11 February 63
2.	Interim Report, Frame-by-Frame Exposure Control Printer, PAR 13, Contract EB-1492	17 January 64
3.	Quarterly Reports, PAR 13, Contract EB-1492	1 July 63 1 October 63 17 January 64 31 March 64 28 June 64